ENGLISH TRANSLATION

Method to Determine a Raw Form of an Elastic Component

Prior Art

The invention starts with a method to determine a raw form of an elastic component in accordance with the pre-characterizing clause of Claim 1.

A method is known to determine a raw form of an elastic, non-articulated wiper arm embodied as a leaf spring with a constant cross section with the default of a target form, which the component is supposed to assume under the effect of a predefined deforming force, in which a raw form is determined by a preliminary bend, whose progression corresponds to that of an elastic, bending beam with one end fixed and whose strength is determined by a bearing force and can be calculated with the aid of known formulae (see Dubbel, *Taschenbuch für den Machinenbau* [Pocketbook of Mechanical Engineering], 19th Edition, Springer Verlag, Berlin, Heidelberg, 1997).

Advantages of the Invention

The invention starts with a method to determine a raw form of an elastic component, in particular a non-articulated wiper arm, with the default of a target form, which the elastic component is supposed to assume under the effect of at least a predefined initial force.

It is proposed that a counter force that at least essentially opposes the predefined initial force is applied to a working model of the elastic component, whose model raw form is at least similar to the target form. As a result, the raw form can be determined advantageously in a purposeful manner, while avoiding multiple attempts and without great mathematical expense. A raw form can be determined, which fulfills both the relevant requirements for a design of the target form as well as the relevant requirements for the function of the elastic component. In the case of a non-articulated wiper arm, it is possible to advantageously achieve a bearing force that has been optimized with respect to wiping quality and wiping comfort with a target form of the wiper arm dictated by aerodynamics and design, which said wiper arm assumes in an assembled state on a motor vehicle. With respect to the aerodynamic properties of the wiper arm, the formation of an intermediate space between the wiper arm in its target form and a wiper blade mounted on the wiper arm adjacent to a vehicle window is of crucial importance.

A form of the elastic component, which said elastic component assumes in a configuration that is essentially free of force, should be understood as a raw form. A form of the working model, which

said working model assumes under the effect of a raw force, which is at least essentially zero particularly in a first step of the method, but can also assume finite values in intermediate steps, should be understood as a model raw form. It is conceivable to design the method with a working model that is at least essentially geometrically similar to the elastic component, if the relevant forces are subject to the same similarity and scale transformations, which a model raw form of the working model carries over to a target form of the elastic component. It is also conceivable to carry out the method with an elastic material for the working model that is different from a material for the elastic component, if the relevant forces are multiplied by the ratio of the corresponding moduli of elasticity. In accordance with Hooke's law, a deformation of an elastic material under the effect of a force is always proportional to this force. This results in various possibilities of an extrapolative determination of a form, which an elastic component assumes under the effect of a force. Therefore, besides the physical exertion of force, partial or complete mathematical simulations of force and methods that include extrapolation and/or scaling steps should also be understood as the application of a force, particularly a counter force.

It is proposed in an embodiment of the invention that the counter force be increased in intermediate steps in the method. Improved control of a deformation movement can be achieved due to the possibility of making adjustments in intermediate steps. Information about intermediate forms can be advantageously acquired.

If, after at least one intermediate step, a current counter force is aligned in its direction at least partially dependent upon a deformation of the working model, non-linear effects can largely be avoided and a situation can be achieved where the deformation process with an elastic component, whose form was determined in this manner, is essentially reversible in each intermediate step.

It is proposed for an embodiment of the method, in which the working model is deformed in a real manner, that the working model be fixed in the raw form by heating and cooling. In doing so, heating the working model in the raw form is meaningful for easing internal material stress of the working model up to a temperature range just under the melting point of the material of the working model. This embodiment of the method is particularly advantageous in the manufacture of prototypes.

In addition, it is proposed that a deformation of the working model be simulated under the counter force. Materials and forms can be varied simply and cost-effectively by changing parameters of a simulation program and one can make use of tested numeric methods. A finite element method can be used especially advantageously in the numeric simulation. In this connection, both a linear as well as a non-linear finite element method is conceivable.

In this case, the form of an elastic component is approximated by simple three-dimensional building blocks, whose deformation can be analytically calculated under the effect of simple fields of force on their boundary surfaces. An overview of finite element methods can be found in the textbook "*Finite-Elemente-Methoden*" [Finite Element Methods] by Klaus-Jürgen Bathe, published in December 2001 by Springer Verlag, Berlin-Heidelberg.

If the finite element method uses a sub-division into finite elements, in which at least a plurality of the finite elements divides a maximum of two separating surfaces with neighboring finite elements, the numeric expense can be advantageously reduced. A particularly simple sequential processing of the deformation of individual elements is made advantageously possible. Particularly in a linear approximation for the equations of the deformation of the elements, the problem of calculating the raw form can be advantageously reduced to the diagonalization of a band matrix and use can be made of quick numeric methods. Particularly in the case of longish components, such as non-articulated wiper arms, high precision can therefore be achieved with a low number of elements and calculation steps.

Drawings

Additional advantages are yielded from the following description of the drawings. An exemplary embodiment of the invention is depicted in the drawings. The drawings, the description and the claims contain numerous features in combination. The person skilled in the art will also observe individual features expediently and combine them into additional, meaningful combinations.

The drawings show:

Fig. 1	A flow chart of a method to determine a raw form of a non-articulated wiper arm.
Fig. 2	A top view of a working model of a wiper arm.
Fig. 3	The working model from Fig. 2 in a model raw form with a counter force applied.
Fig. 4	A non-articulated wiper arm in a raw form and under the effect of a bearing force.
Fig. 5	A schematic representation of a test phase of the method.
Fig. 6	A schematic representation of a division of the working model into finite elements.
Fig. 7	A schematic representation of a deformation of a finite element under the effect of a longitudinal force.
Fig. 8	A schematic representation of a deformation of a finite element under the effect of a transverse force.
Fig. 9	A schematic representation of a deformation of a finite element under the effect of a bending moment.
Fig. 10	A schematic representation of a calculation of an entire deformation of a finite element of the working model from Figs. 1 through 9.

Description of the Exemplary Embodiments

Figure 1 shows a flow chart of a method to determine a raw form of an elastic component embodied as a non-articulated wiper arm 10 with the default of a target form, which non-articulated wiper arm 10 is supposed to assume under the effect of a predefined initial force F_1, which represents a counter force to a bearing force of the wiper arm 10 on a vehicle window (Fig. 4). In a definition step 18, parameters of the desired target form are fed into a memory of an arithmetic-logic unit, which uses a finite element method to simulate a deformation of a simulated working model 12 of the non-articulated wiper arm 10 in the case of a counter force F_G opposing the applied initial force F_I (Fig. 3). A model raw form, which the working model 12 assumes in a configuration that is free of force, is depicted as a solid line in Fig. 3 and is identical to the target form of the non-articulated wiper arm 10, which is depicted as a dotted line in Fig. 4. To simulate the deformation, boundary conditions are selected in such a way that a fastening plane 14' of the working model 12 remains fixed. The fastening plane 14' corresponds to a fastening plane 14 of the wiper arm, which is in an area of the wiper arm 10, in which the latter features an opening 16 for inserting and screwing down a drive shaft. In a deformation phase 20, the counter force F_G is increased in several intermediate steps up to its end value, wherein in each intermediate step a current counter force F_G is aligned perpendicular to a surface of said working model dependent upon the deformation of the working model 12.

The parameters of the form, which the working model 12 assumes under the effect of the counter force F_G at its end value, are output during an output step and represent the desired information about the raw form of the non-articulated wiper arm 10.

This information can now be used in a test step 24 to simulate elasticity properties of a wiper arm 10 with the calculated raw form. To do this, the effect of a test force F_T on the wiper arm 10 is simulated with the raw form determined in the first steps 18, 20, 22 of the method (Fig. 5). If the test force F_T is gradually increased from zero to the value of the initial force F_1, wherein the test force F_T is aligned perpendicular to the surface of the wiper arm 10 in every intermediate step, the wiper arm 10 deforms from the raw form to the target form. To determine the bearing force variations during a stroke movement 26, the test force F_T is varied slightly by the initial force test force F_1 and a deflection is assumed as function of the test force F_T, i.e., an inverted spring characteristic of the wiper arm 10 (Fig. 6). A flat spring characteristic is advantageous in the area of the bearing force, because the stroke movements 26 in this case generate only small variations of the bearing force and therefore only have an insignificant effect on wiping quality.

Fig. 10 shows a schematic representation of a simulation of the deformation of a finite element E_i of the working model 12. The simulation algorithm starts with a solid fixing at the fastening plane 14' of the working model 12. There the deflection and angle change are always zero. The working model 12 is divided into finite elements E_1 - E_N along its longitudinal extension, the deformations of said finite elements are calculated individually and added up (Fig. 6). Each of the finite elements $E_2 - E_{N-1}$ divides two

separating surfaces with neighboring finite elements $E_1 - E_N$, while the finite elements E_1 and E_N situated on an end each only have one neighboring finite element. In areas with stronger cross-sectional or stress changes, finer sub-divisions are selected than in those with approximately the same cross section and the same stress. The target form of the wiper arm 10 is approximated as a stepped form by the model raw form of the working model 12, in that it is assumed in the modeling that the finite elements E_i have constant cross sections over their length l_i.

The position of each finite element E_1 - E_N is stored in a center of gravity $v_1 - v_N$ with center of gravity coordinates $x_1 - x_N$, $y_1 - y_N$ and in an angle $\phi_1 - \phi_N$. A longitudinal force F_{li} (Fig. 7), a transverse force F_{qi} (Fig. 8) and a bending moment M_i (Fig. 9) act on each finite element E_i at the boundary surfaces. The bending moment M_i is calculated as the torque in accordance with $M_i = \Sigma_j F_j * s_{ij}$ from the forces $F_j = F_{lj} + F_{qj}$ on all finite elements E_j, $j = 1 \ldots N$ and from the distance vectors $s_{ij} = v_i - v_j$ between the finite elements i and j. The vector product is designated here with "*". Starting with finite element E_1 on the fastening plane 14', the centers of gravity v_i and the angles ϕ_i are inductively calculated for $i = 2 \ldots N$. Starting from a displacement δx_{i-1}, δy_{i-1}, in a first step, the center of gravity v_i of the finite element E_i is displaced by the same displacement vector and switches over to a center of gravity v_i' (Fig. 10). Subsequently, the center of gravity v_i' is rotated by an angle change $\delta\phi_{i-1}$ around a center of gravity v_{i-1} of a neighboring finite element E_{i-1} and switches over to a center of gravity v_i''.

The deformation of the finite element E_i with a constant cross section under the effect of a transverse force F_{qi}, a longitudinal force F_{li} and an external moment M_i depends upon the length l_i of the finite element E_i, upon an area moment I_i of the cross-sectional surface A_i of the finite element E_i and upon a material-dependent modulus of elasticity E. In particular the following is yielded:

$$\delta\phi_i = F_{qi}l_i^{2}/(2I_iE) + M_il_i/(I_iE)$$

$$\delta y_i' = F_{qi}l_i^{3}/(3I_iE) + M_il_i^{2}/(2I_iE)$$

$$\delta x_i' = F_{li}\, l_i/(A_iE)$$

In this case, the displacements $\delta x_i'$ and $\delta y_i'$ refer to a coordinate system, whose coordinates run tangentially to the progression of a flexional curve of the working model 12 at the location v_i. This results in a new angle $\phi_i = \phi_{i-1} + \delta\phi_i$ and a new center of gravity v_i''' with the following coordinates:

$$x_i''' = x_i'' + \cos(\phi_i)\, \delta x_i' + \sin(\phi_i)\, \delta y_i'$$

and

$$y_i''' = y_i'' + \cos(\phi_i)\, \delta y_i' - \sin(\phi_i)\, \delta x_i'$$

To conclude the induction step, the angle change $\delta\phi_i$ and the elastic displacements $\delta x_i = x_i''' - x_i$ and $\delta y_i = y_i''' - y_i$ are included in the calculation of the coordinates and the angle for the next finite element E_{i+1}.

If the deformation of all N finite elements $E_1 - E_N$ is concluded, the angles $\phi_1 - \phi_N$ and the centers of gravity $v_1''' - v_N'''$ are saved as information for the raw form of the wiper arm (10).

Analogous to the finite element method described above, a wiper arm 10 is simulated in the test phase 24 and said wiper arm is described in a configuration that is free of force via the finite elements with the centers of gravity $v_1''' - v_N'''$ and the angles $\phi_1 - \phi_N$.

Reference Numbers

10	Wiper arm	M_i	Bending moment on E_i
12	Working model	F_{qi}	Transverse force on E_i
14	Fastening plane	F_{li}	Longitudinal force on E_i
16	Opening	l_i	Length of E_i
18	Definition step	A_i	Cross-sectional surface of E_i
20	Deformation phase	v_i	Center of gravity of E_i
22	Output step	x_i	Coordinate
24	Test step	y_i	Coordinate
26	Stroke movement	δx_i	Change of the coordinate
E_i	Element No. i	δy_i	Change of the coordinate
s_{ij}	Distance vector	ϕ_i	Angle
F_1	Force	$\delta\phi_i$	Change of the angle
F_G	Counter force		
F_T	Test force		